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The Practical Working of the Electrical Subways of New York City.

BY WILLIAM MAVER, JR.

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A paper read before the 43d meeting of the American Institute of Electrical Engineers, New York, February 18, 1890, and discussion thereon. Vice-President T. C. Martin in the chair.

THE PRACTICAL WORKING OF THE ELECTRICAL SUBWAYS OF NEW YORK CITY.

BY WILLIAM MAVER, JR.

Knowing very well the widespread interest that has attended the placing of wires underground in New York City, I have been glad of the opportunity to gather and prepare for presentation to you this evening such data and information relating to that subject as I have thought would be, and as I hope may be, found of the most value.

I observe that our worthy secretary has announced me in the notice of the meeting as the electrician of the Consolidated Telegraph and Electrical Subway Company, and quite correctly so. I desire to say, however, perhaps unnecessarily, that I have prepared this paper in my unofficial capacity, and am, of course, alone responsible for what may be contained therein.

The customary reply to an inquiry as to what is the best arrangement for an electrical subway is, "Build a tunnel under the streets and place the wires on the walls within easy access of workmen and into such a tunnel put also the gas and water mains, etc."

Assuming that this would be a satisfactory solution of the underground question if it could be arranged, let us consider what the cost of such an arrangement would be.

It has been estimated that a subway suitable to contain all the electric wires, gas and water mains of New York City would cost $430.000 per mile. This for Broadway alone, from Bowling Green to Central Park, would mean an outlay of about $2,150,000, and if such a tunnel were to be built throughout the entire route of the now existing electrical subways of New York City, the bill would foot up to nearly $30,000,000.

This amount, it will, I think, be generally admitted, is virtually prohibitory of any such subway at present, and if that is the case the fact will perhaps make those who have had preconceived ideas in favor of a universal tunnel scheme more tolerant of the electrical subways we have, the practical working of which I am to endeavor to describe this evening.

When the first whisperings of a desire on the part of the public or press to have electric wires in the large cities go underground were heard in this country, it will be remembered the telephone people with one accord admitted that it would be quite feasible for the telegraph and electric light people to operate their wires underground, but claimed that for them to attempt to thus operate their circuits meant irretrievable ruin. Equally convinced also were the telegraph people that while it would be very easy for the electric light companies to work their circuits underground, it was quite out of the question that telegraph wires could be operated successfully in subways, since the increased electro-static and electro-magnetic effects would completely destroy quadruplex and fast automatic telegraphy. And no less emphatic was the opinion of the high-tension electric light people that the telegraph, the telephone and the low-tension electric light systems could, if required, all go underground without detriment, but it was utterly impossible for them to do so and at the same time to operate their circuits successfully.

New York City was no exception when the time came to place the wires underground. Gradually, however, the telephone yielded—more gradually the telegraph, but more tenaciously the majority of the high-tension people clung to their statements, and the experiences of the cities of Chicago and Philadelphia, especially Philadelphia, and elsewhere were cited as evidence of the futility of any attempt to operate high-tension currents underground. These experiences were held to show that no insulation could be procured which would withstand the pressure of the high electromotive force employed on high-tension circuits. In addition to this it was also asserted that the requirements of the Subway Commission regarding the insulation resistance of the underground conductors was high beyond all precedent and unobtainable in practice, and that even if such insulation could be obtained it would be impracticable to make tests of the conductors, showing them to possess the insulation resistance required by the rules.

It is very far from my intention to go into a history of the opposition offered by the different electrical companies to placing their wires underground, and in-so-far as I have just alluded to it I have done so for the purpose of quoting in a general way some of the reasons given by the companies for this opposition, and this only, that we may see how far the surmises of those who were thus averse to placing wires underground have been verified by actual results.

It is told of a certain noted geologist that when a specimen of gold quartz, which had been found in a locality where he had stated no gold would ever be found, was shown him, he remarked that if it really had been found there, nevertheless it had no right to be there.

I can imagine that there are many persons—perhaps not in this room—but somewhere, who, if told that the telephone, telegraph, high and low tension electric light circuits, and even "deadly" alternating circuits, are to-night in this city working successfully underground in the same streets and on the same side of the streets, would reply, "If they really are working successfully there, they have no right to be."

In preparing this paper I have found that the subject has almost naturally arranged itself under the following general headings, namely:

The type of conduits used in the subways.
The drawing in of cables.
The methods of distribution.
The cables employed in the subways.
Present condition and probable duration of cables.
Joints.
Lead covered cables.
Insulation and tests.
Alleged dangers of the subways.
Gas in the subways.
General remarks.

I have been unable to obtain, with any degree of accuracy, the extent of electrical subways or the amount of wire placed in them in the cities of Europe, and, therefore, I cannot say definitely how New York to-day compares with such cities as London, Paris and Berlin in that respect. But I incline to the belief that it may be found that New York will fall but little, if at all, behind those cities. In New York City, to-day, there are 73 miles

of electrical subways, and 1,017 miles of ducts. In these ducts there are 10,906 miles of telephone wire, 945 miles of telegraph wire, including fire alarm telegraph wires, and 457 miles of electric light wires. These subways have capacity for abont 45,000 miles of telephone and telegraph wires and 2,000 miles of electric light wires.

CONDUITS.

There are in the New York electrical subways eight different conduit systems—namely, the Dorsett, the Wyckoff, zinc tubing in hydraulic cement, sheet iron cement-lined pipe, wrought-iron pipe in hydraulic cement, wrought-iron pipe in asphaltic concrete, the Edison iron tube and the Johnstone sectional cast-iron conduits. All of these conduits have been frequently described; I shall therefore just briefly refer to each.

The Dorsett system consists of blocks formed of a material the ingredients of which are pitch, coal tar and fine gravel. The blocks are moulded, with tubular openings about 2½ inches in diameter from end to end. The blocks are about 4 feet long and 1 foot cross section. These blocks are placed end to end in the trench, and are joined together by pouring between the ends a liquid compound of pitch and tar, which speedily hardens. This compound is prevented from entering the ducts by sleeves, which are placed in each duct between the junction of every two blocks. There is about one mile of this conduit, containing 16 miles of ducts, on Sixth avenue. It is used for telephone and telegraph conductors. This conduit was laid three years ago. So far as I can learn, it is in a fair state of preservation to-day—but not perfect; the blocks having in some instances sunk, and thus put the ducts out of alignment. It may be noted here that guide ropes, consisting of ¼-inch tarred hemp, which were laid in these ducts when this system was constructed, to be in readiness when cables were to be drawn in, show plainly in numerous places signs of deterioration, said to be the result of dry rot, combined with the gases found in the ducts.

The zinc tube conduits are laid in 58th street. The zinc tubing was intended to serve simply as a mould around which hydraulic cement concrete was to be placed, with the expectation that when the zinc had corroded, the tube formed by the solid cement would remain intact. About one mile of this conduit has been in successful operation for three years, but the difficulty attending *the construction* of a conduit formed in this way was so great, owing

to the frailty of the zinc tube, which readily gave way under moderate pressure, that its use has not been further extended.

The sheet iron cement-lined pipe conduits are made in single or multiple tubes of 2, 4, 6 or more ducts, as may be required and in lengths of 8 feet. The tubes are connected together by a ball and socket joint. These conduits are made as follows; a sheet iron tube 8 feet in length is held vertically; inside of the tube is placed a smaller brass tube, and semi-liquid cement is poured into the annular space between the brass and sheet iron tubes. When the cement has solidified the brass tube is withdrawn. The cement tube is then ready for the subways. There are about 113 miles of ducts of this conduit in the subways, and during the coming summer it is expected many times this amount will be laid in New York City.

There are about 15 miles of creosoted wooden ducts in the subways known as the Wyckoff conduits. These ducts are formed of wooden piping similar to ordinary pump logs. There are lead-covered telephone cables in these ducts, and the action of the creosote upon the lead covering is being carefully watched. These ducts have been in operation for three years. I am informed that detrimental effects are noticeable in the lead covering of the cables, which is alloyed with 3 per cent. of tin.

The bulk of the subway conduits consists of wrought-iron pipe laid in hydraulic cement concrete. These pipes are 20 feet in length and vary in diameter from 2 to 3 inches. The thickness of the iron is .217 inch.

In laying all of these pipe conduits, the bottom of the trench is first levelled to grade; planks are then set against the side of the trench to sustain it. A layer of concrete is then laid and rammed in the bottom of the trench. On this is placed a row of iron pipe, next a layer of concrete, then another row of pipe, and so on, until the desired number of layers is attained. The number of pipes in a row depends upon the topography of the street and the location of existing gas and water pipes which it is desired to avoid, and the number of rows upon the total number of pipes desired to be laid in a given subway. In order to add strength to the mass and to protect the ducts from mechanical injury, the concrete is applied more thickly on the bottom, top and sides of the subway than between the pipes. There is placed over all a two-inch yellow pine planking, heavily creosoted, to further protect the conduits against injury from picks, crow bars, etc., in the event of future excavations in the streets. (See Fig. 1.)

The wrought-iron pipes are joined end to end by a coupling screw joint with a tapering or vanishing thread. By the use of this form of thread, I am informed the rate of laying this piping is increased 50 per cent. These tubes are delivered free from burrs and have a smooth inner surface. The pipes are sometimes asphalted to prevent rusting, but should they in the course of time rust, it is expected, as in the case of the zinc tube, that the concrete will preserve the shape of the duct intact. There are close upon 550 miles of wrought-iron piping in the subways.

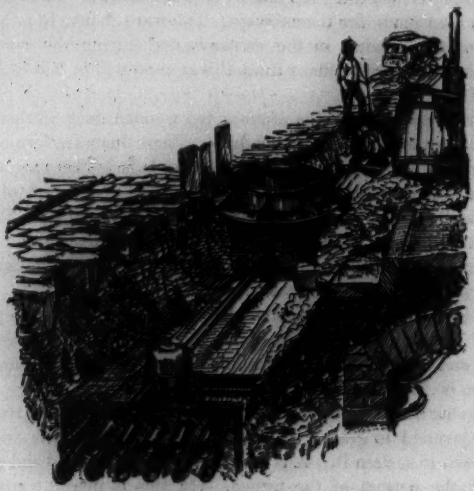

Fig. 1. Iron Pipe and Cement Conduit.

The facility with which a pipe conduit conforms to the varying condition of the crowded streets of large cities, as found in the process of trenching, is one of its chief advantages.

The main reasons which have led to the extensive use of wrought-iron piping in the subways are its great strength, its adaptability to varying conditions of the street and the rapidity with which it can be laid.

The Edison system consists of wrought-iron pipe in which are placed the copper conductors or rods. These conductors are wound with rope and the pipe is filled with an insulating com-

pound of Trinidad asphaltum, rosin, paraffin and linseed oil. These iron pipes are laid directly in the earth. There are about 50 miles of this pipe now laid in New York City.

The subways are in many cases on both sides of a street, and, as a rule, the telegraph and telephone wires are assigned to ducts on one side of the street, and the electric light wires to ducts on the opposite side; but in numerous instances the electric light wires are operated in distributing ducts on the same side of the street as the telegraph and telephone wires, and without detriment to the latter. In no case, however, do the telegraph and telephone ducts inter-communicate with the electric light ducts, and separate manholes are provided for each.

MANHOLES.

Access is to be had to the conduits of the New York subways by means of manholes, placed at an average distance of about one-twenty-fifth of a mile apart. The manholes are, with a few exceptions, built of brick laid in concrete cement, with hydraulic concrete bottom. The outside of the walls is coated with cement, to prevent moisture and gas from penetrating.

Access to the manholes from the street is had through the cast-iron head which is set on the brickwork and which is provided with double covers. The upper or street cover weighs about 350 pounds. The lower cover is provided with a rubber gasket to prevent ingress of street water into the manhole. This cover is funnel shaped in order that any water which may enter through the upper cover may be drained away from the gasket. The lower cover is screwed down upon the gasket by a gun metal bolt and cross bar. The upper cover is loose upon its bearings. The ducts enter the manholes at a point easily accessible to the workmen while standing on the bottom of the manhole. The manholes average in width about five feet and vary from five to ten feet in depth. The drawing, Fig 2, shows a standard manhole of the New York subways. The hand blower used for driving out gas from the manholes is shown, also the iron framework or cage which is placed around the opening to the manholes when the cover is removed.

The foregoing mentioned conduits may be considered as belonging to the regular subway system of New York City.

There are, however, several other conduits in operation in this city, namely, the Brooks, the Western Union, and about five

miles of telephone cable laid in wooden boxes filled with sand. The Brooks system has been so repeatedly described I need not further allude to it. The Western Union subway consists of an iron pipe about six inches in diameter into which wires have been drawn.

FIG. 2. STANDARD MANHOLE.

RODDING.

The electrical subways of New York City, with the exception of the Edison system, are of the class known as the drawing in and out systems. The first process in drawing a cable through a duct which is not easily accessible except at its ends in the manholes is obviously to provide a means of drawing in the cable.

This is done by a process technically termed rodding, which consists of pushing rods through the duct from one manhole to the next. A rope is then attached to the end of the rod and the rod is withdrawn bringing the rope with it. This rope is then employed to haul in the cable. As some of the manholes are over 500 feet apart, and it would not be convenient to procure a continuous wooden rod of that length, rods of about four feet in length, furnished at one end with a screw and at the other end with a screw socket, are used. These are placed in a bunch in the manhole and are attached by the screws one to the other, as many as are required to reach to the distant end of the duct. The rods are then detached, as they are drawn out, by unscrewing the ends. This is a specimen of this form of rod. (Showing.) It is the one most generally used. There are other forms of rod also in use in the subways. This (showing) is one of them. It is furnished with a slot into which the T end fits, but into or out of which it can only go at a certain limited angle. Therefore, while this joint or connection is quite loose, there is no likelihood of the rods coming apart in the duct because the diameter of the ducts does not permit a sufficient movement of the rod at the joints. The time taken in rodding a duct 300 feet in length is about 20 minutes.

A continuous steel wire rod about one-quarter of an inch thick and from 400 to 500 feet long is also used for rodding the ducts. This rod is mounted on a reel about 6 feet in diameter, which is placed adjacent to a manhole, and from which it is reeled off as it is pushed through the duct. When this operates freely, it is more expeditious than the wooden rod methods just described, as the time taken in jointing up the rods is saved; but it is found that the wire occasionally buckles in the duct, and, furthermore, it is more apt to be caught by any obstruction or unevenness, than are the wooden rods, so that by many the latter are employed as being the more expeditious, all things considered.

There is also another means of rodding sometimes employed, which consists of a long spiral steel rod, the spiral of which is about one inch in diameter. On the circumference of the spiral small wheels are mounted to ease the friction. This rod is also placed on a reel and wound off as it is fed into the duct. This spiral, while quite elastic, is yet capable of withstanding considerable pressure. This rod is pushed into the duct in the usual way. The expense and the weight of this form of "rodder" is some-

what against it, although I am informed that by its use a duct can be rodded in one half the time required by the screw rods.

Before those employed in the work of drawing conductors into subways had devised and settled down to the forms of rods just described, many bright minds were at work on the question of how to rod the ducts. The scheme of tying a string to a rat's tail and sending him through the duct with a ferret after him was tested practically in Brooklyn, I believe, but the plan was not generally adopted. In the case cited, it is stated that the ferret overtook the rat, and stopping to eat him, was overcome by the gas and asphyxiated. This necessitated the tearing up of the street to get at the remains.

In Chicago, it was seriously suggested that a wooden ball with a string attached to it be placed in the duct, and that then a hose connecting with a neighboring hydrant be inserted in the duct. The water was to force the ball through the duct. This plan was found to work successfully so far as getting the ball through was concerned, but it flooded the manholes, and was not put into general use, even in Chicago.

Another inventor devised what he called a mechanical creeper, which was designed to advance itself through the ducts by putting out arms against the walls and thus pushing itself along.

Sometimes, in rodding, obstructions are met with, caused by pieces of cement, stone, dirt, etc., gaining access to the ducts. Sometimes, also, obstructions are caused by uneven joints in the conduits. Ordinary obstructions are removed by a mandrel placed on the first rod.

DRAWING IN CABLES.

After the rope has been attached to the cable, the latter is then "threaded" through the duct. The attaching of the rope to a cable is a matter of some skill. The connection is so made that the strain comes chiefly on the conductors. To prevent the cable or cables from twisting as drawn in, a swivel is inserted in the rope near the cable.

The manner of applying the force necessary to pull the cable through the duct depends upon the size and length of the cable. If it is a small cable, say 300 feet in length, it can be drawn in by two or three men. If it is a large cable, or if four or six small cables are to be drawn into one duct, as is frequently done, more elaborate drawing-in apparatus is used. This generally consists of some form of winch, such as is shown in Fig. 3, which very

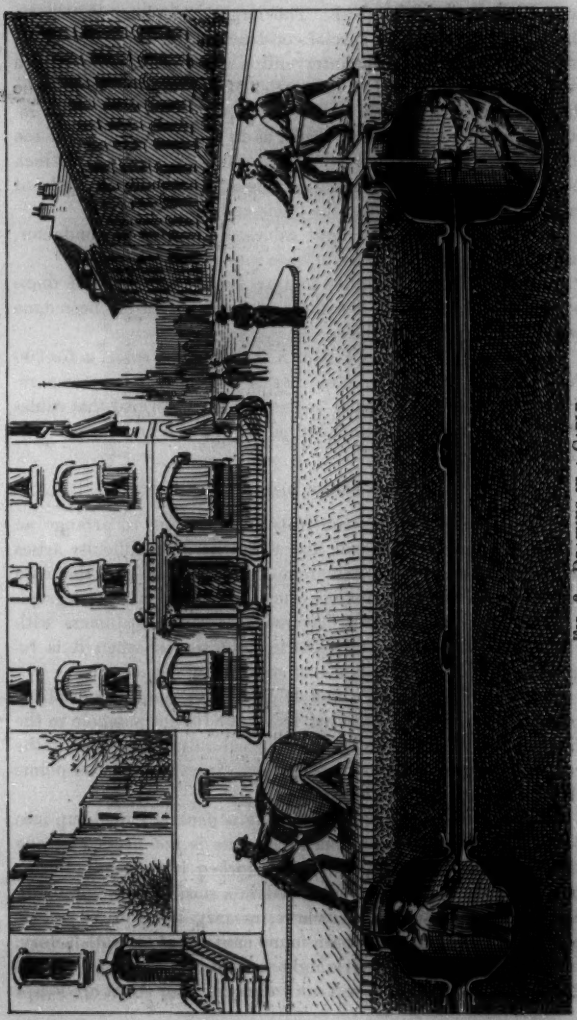

FIG. 3. DRAWING IN A CABLE.

well illustrates the method. The largest telephone cables are drawn in by a winch of special construction, in which the power is transmitted through the intervention of wheel gearing. As a rule, it may be said that in the matter of drawing cables into the ducts the work has been satisfactorily performed. In a few instances mistakes have been made, as in the attempt to draw too many cables into one duct—the old problem of putting a 3-inch bung into a 2-inch hole—and in the attempt several lengths of cable have been jammed in the ducts and injured.

As many as six electric light cables, No. 4 B. & S. conductor, have been repeatedly drawn at once into a 3-inch duct.

It is not deemed advisable to draw cables into or out of ducts over cables already laid, but in cases of necessity it has been done without injury to the cables.

As the weight of a No. 4 B. & S. lead covered cable, is for 300 feet, say 250 pounds, an idea may be obtained of the force required to draw in six such cables. I am informed that cables weighing in the aggregate 5,510 pounds have been drawn at one time into one duct.

METHODS OF DISTRIBUTION.

It is, of course, a comparatively easy problem to arrange an electrical subway for trunk line circuits. The difficulty arises when the question of distribution of the current from the main conduits is to be considered, as when, in the case of the telegraph and telephone service, it is desired to furnish customers with circuits, and in the case of electric light service when it is required to make house to house or street lamp connection.

In the case of telegraph and telephone distribution subsidiary pipes or ducts are generally led from an adjacent manhole to the front or side of buildings, whence the cables are continued to the roof of the building or to the back yards, from which latter points the circuits are radiated as required.

The cable of the telephone company is generally made up into 50 pairs When this number of circuits is not needed in one block or series of blocks, the cable is forked in the manhole, one portion of the conductors being led in a smaller cable in one direction, another portion elsewhere, as may be required. This method of distribution has been found convenient and satisfactory.

Distribution of the electric light current is effected in several different ways in the New York subways. For street arc lamps

the circuit is usually looped from the manhole to the lamp post through a subsidiary iron pipe.

For easy access to houses and to lamps in the middle of blocks distributing ducts are laid above the trunk ducts as near the surface of the street as practicable. The average distance from the surface of the street being perhaps 18 inches.

The Johnstone sectional conduit, Fig. 4, has hitherto been the

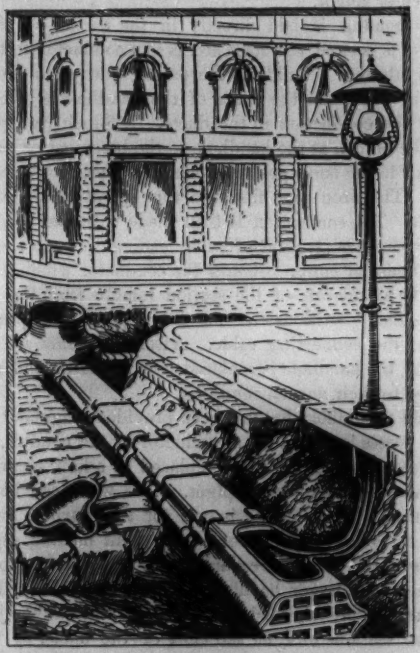

FIG. 4.—JOHNSTONE SECTIONAL CONDUIT.

most extensively employed for this purpose in New York City. This conduit consists of sections of cast-iron ducts about 5 feet in length. The sections are placed directly above each other and are held together when in position by removable clamp pins. The upper section rests in a groove in the lower section. Each section of the conduit is divided into from two to six or more

compartments or ducts—depending upon the size of the section—the ducts being formed by removable partitions or slats held in position by suitable channels or grooves within the sections. Opposite each house or every alternate house a "handhole" is provided in the upper section of the conduit. This handhole consists of a removable cover, about 2 feet in length, on the upper section, and the side of the section at this point is provided with a branch or spigot.

This conduit is laid directly in the earth—not in cement. When it is desired to obtain access to a conductor to tap or loop the circuit into a building, the paving and earth are removed from the street and the cover of the handhole is lifted, thus exposing the conductors in the ducts. A 3-inch iron pipe is run from the branch at the handhole to the basement or vault of the house or to the lamp post with which connection is desired to be made. This iron pipe fits onto the spigot at the side of the conduit. The connection is then made with the conductors by splicing on short lengths of cable leading through the iron pipe to the house or lamp. Should the conductor which it is desired to tap be at the side of the section remote from the spigot, the intermediate partitions are removed to permit the passage crosswise of the connecting cable. After the joints are made, the cover of the handhole is replaced and the earth and paving are restored to their normal condition.

When a handhole has not been provided originally at a point where access is desired to a conductor in the conduit, the entire upper section is removed and replaced by a half section containing a handhole cover and spigot. This work can be done in a short time. The sections in use for this purpose are, in some instances, somewhat small for ease in joint making, especially, as but very little slack is available when T joints are to be made, and, in future, larger handholes will be provided. These conduits are presumably made air and water tight at the junction of the two sections and, at the ends of the ducts, by the use of plumbers' putty. In view of the number of supposed opportunities for the entrance of moisture at these junctions, it would be naturally expected that this type of conduit would be in a chronic moist condition. Indeed it has been predicted of it that the ducts would act as canals for the surface water; but, as a matter of fact, these ducts are almost invariably dry. There are two theories given to explain this fact. The first, that in reality the

plumbers' putty makes an air and water tight joint. The second, that if the joints are so imperfect as to admit water, they are quite capable of permitting its escape also. It must be said that this system has been found of much utility in the practical distribution of electric light current in this city.

More recently a method of distribution in which wrought-iron pipes are used has been employed. This consists of a row of three or four iron pipes laid, like the Johnstone conduit, as near the surface as possible—in the earth, without concrete. Opposite every party wall, or, in other words, at distances of about 50 feet apart, iron boxes about 18 inches square are placed. These boxes have removable covers. The ducts enter at the ends of the box but do not pass through it. The boxes are provided with side openings also for the entrance of the subsidiary iron pipes. Access is had to these boxes also by the removal of the street paving and earth.

This method of distribution has, like the one just described, been found satisfactory. Certain mechanical improvements in the construction of both are, however, desirable, and are contemplated. (See Fig. 5.)

When it is desired to cross a street to reach customers subsidiary ducts are constructed.

It is frequently remarked, presumably derogatory of the existing electrical subways, that no system of house to house distribution can be considered perfect which requires the tearing up of any portion of the street to obtain access to the mains. This will be granted by any one. The same is equally true of the house to house distribution of gas and water from the street mains. In all of these cases, if the connections were made from the street mains to every house and vacant lot along their routes when the mains are first laid, the necessity for reopening the streets to make house connections would be avoided. But I have yet to learn that this is done by either the gas or water companies, nor have I heard that their neglect to do so has been seriously animadverted upon.

It would, therefore, seem unreasonable that the additional expense of making these connections, which may never be required, should be urged upon the users of the subways by any who have the interest of electrical industries at heart, especially while they ignore the failure of the gas and water companies to make corresponding connections.

THE CABLES EMPLOYED IN THE SUBWAYS.

In the telephone service in this city, the cables used are chiefly of the type known as the Patterson. This cable is constructed as follows: Ordinary cotton covering is first placed around the wires. After the wires are cabled, a lead covering is placed over

FIG. 5. DISTRIBUTING DUCTS AND AIR PIPE.

them, and paraffin is then forced into the interstices between the conductors and lead covering.

This cable has an electro-static capacity of about 0.16 microfarad. The insulation resistance of the cable, laid and jointed in the subways, averages about 100 megohms. The longest stretch

of cable used by the telephone company in the subways is seven miles. The greatest number of conductors in any one cable is 100 or 50 pairs.

The telephone service on the underground conduits was impaired somewhat, so long as ground circuits were used, but since the adoption of metallic curcuits the service is satisfactory. On the long distance telephone circuits the seven miles of cable is, of course, somewhat detrimental. It is said the loss of efficiency on such circuits is 30 per cent.

The telegraph companies have thus far used chiefly for underground service Kerite, Okonite, Standard Underground and Patterson cables. The Kerite and Okonite insulation, it is well known, are homogeneous compounds. These cables are not lead covered. Of course they could be. The Standard and Patterson are fibrous cables and are lead covered.

Except in the vicinity of the underground steam pipes, the unprotected homogeneous cables have given satisfaction. But as might be expected, the effect of a continued high temperature upon them has been detrimental.

Fortunately the heated area in the vicinity of the electrical subways is limited to a portion of the down-town districts. Investigation has shown that the heat only reaches a harmful temperature in the neighborhood of actual leaks in the steam pipes. Measurements of the temperature of a manhole in the worst section of the heated district have shown as high as 150 deg. to 200 deg. F. Since the starting of the blowers in this district to ventilate the subways, a noticeable decrease in the temperature is observable, and, inasmuch as the steam heating company is achieving some success in its efforts to close up all leaks in the pipes, it is anticipated that the heat difficulty will be eventually removed from the subways.

The users of the Standard and Patterson cables state that those cables are giving very fair service in the heated portions of the subways, although the high temperature, of course, very materially lowers the insulation resistance of the cables.

The average number of conductors in the telegraph underground cables is about 50. The size of the wire used is, as a rule, No. 16 B. W. G. and the outside diameter of a conductor, including the insulation, is 6-32 of an inch. The insulation resistance of the Okonite insulation is about 2,500 megohms; that of Kerite 500 to 800 megohms and that of the Standard and Patterson

about 1,500 megohms per mile for the thickness of insulation just mentioned.

Outside of the injury to the cables due to the presence of the steam-heating pipes, no undue deterioration of the telegraph cables in the subways has been noted.

The increased electro-static capacity of the underground circuits has not caused any marked inconvenience in the operation of the telegraph circuits.

The comparatively low mileage of telegraph wire in the subways is partly explained by the fact that the bulk of the telegraph circuits in New York City are suspended from the Elevated Railroad structures.

The Fire Alarm Telegraph cables in the subways do not differ very materially from those used by other telegraph companies. The Fire Department thus far has used Standard Underground cables.

ELECTRIC LIGHT CABLES IN SUBWAYS.

In the electric light service in the subways, and I am aware that it is around this that the greatest interest centres, there are, exclusive of the Edison, four different types of cable used—namely, the Bishop Rubber Compound, the Standard Underground, the Safety Insulated and the Cobb Vulcanite Paraffine cable. All of these cables are lead covered as a precaution against mechanical injury, action of acids, etc., or moisture. Specimens of these cables are on the table.

The sizes of conductors used in the electric light service vary with every company and with the character of the service. For feeders the conductors range in size from No. 000000 B. & S. to No. 2 B. & S. For mains from No. 2 to No. 6 B. & S. In many instances No. 10 B. & S. is used for connecting from the mains to lamps through the subsidiary ducts.

THE STANDARD UNDERGROUND CABLE.—The insulation of the Standard Underground cable is obtained by first wrapping thick cotton thread or cord around the wire to any desired thickness. The wire thus covered is then placed in a cauldron of boiling insulating compound—a product of petroleum. This treatment displaces any moisture that may be in the cotton thread. After the cotton has been thoroughly saturated with the compound the whole is then lead covered.

There are now in actual service for electric lighting purposes in the New York subways over 95 miles of this cable, forming

parts of currents having an E. M. F. of from 300 to 3,000 volts, including many 1,000-volt alternating circuits, and an additional 50 miles of the same cable will shortly be in operation. The thickness of insulation used in these cables is 5-32, 6-32 and 7-32 of an inch. This refers to the thickness of the insulation from any given point of the circumference of the conductor.

THE "SAFETY" CABLE.—The insulating material of the Safety cable is an india-rubber compound. It differs somewhat, I believe, from the ordinary run of india-rubber compound cables in that the compound is placed over the wire, without seams or laps of any kind. This compound is vulcanized to a moderate degree of hardness sufficient to prevent decentering of the heavy conductors which it insulates, but yet it retains a high degree of flexibility.

The thickness of insulation used on No. 4 Brown & Sharpe wire—.204 inch diameter—is .108 inch. The weight of this conductor, lead covered, is 4,861 pounds per mile. Of this the wire weighs 665 pounds, the insulation 669 pounds, the tape 95 pounds, the lead covering 3,432 pounds.

A special thickness of this insulation was made in one instance in response to a call for cable to withstand a strain of 7,000 volts for arc lighting. A sample of this cable is on the table—the thickness of the insulation is .238 inch. The conductor is No. 4 B. & S. gauge. This cable is now in the subways. Its length is about three miles. I am not aware that it has yet been called upon to withstand the prescribed 7,000 volts.

There are now over 65 miles of the Safety cable in actual use in the subways, assigned to electric light circuits—continuous and alternating—of from 1,000 to 2,500 volts E. M. F., and about 15 miles additional are now being placed in subways.

THE BISHOP RUBBER COMPOUND CABLE.—The Bishop Rubber Compound Cable is of the well-known Silvertown type, having first a coat of rubber without sulphur, then a coat of rubber compound with sulphur, and over this a lapping of rubber cable, which is then taped. There are two sizes of this cable in the subways; namely: No. 4, B. & S., and No. 6, B. & S. The thickness of the insulation is 4-32 inch; the thickness of the lead covering is 5-64 of an inch, the outside diameter of the cable is .65 of an inch, and the weight of the cable is about 4,600 pounds per mile. There are of this cable, in successful operation, about 10 miles assigned to alternating circuits of 1,000

volts, and five miles to arc circuits of 2,500 to 3,000 volts E. M. F. Double this amount of this cable will soon be laid for similar purposes.

THE COBB VULCANITE-PARAFFINE CABLE is of a somewhat unique construction and design. It also differs materially in one respect from the other cables described, in that the conductor is freely movable within its insulating medium. The cable is made in practically the following manner: A vulcanite tube is first made in lengths of about 300 feet. This tube is moderately flexible. The tubing is vulcanized in boiling paraffine. The wire is then threaded through the tube, after which the sections of tubing are jointed together. A thick cord is then wound spirally around the vulcanite tube. The whole is then lead covered, and the space between the vulcanite and lead formed by the spirally wound cord is filled with paraffine.

There are about twenty-five miles of this cable in the subways.

In the case of the Bishop, Safety, Cobb and Patterson cables, the lead is alloyed with about 3 per cent. of tin. The lead covering of the Standard Underground cable is unalloyed, but it is covered with a thick cotton braiding soaked in "P. & B." paint (the latter a product of petroleum), which, it is claimed, will protect the lead from acid, gases, etc., and the braid also acts to protect the lead from mechanical injury.

CONDITION OF THE CABLES.

I may say that all of these cables are guaranteed by the manufacturers for three years. This term, however, is not to be taken as signifying the limit placed upon the life of the cables by the manufacturers.

It is over a year since current was turned on the first high tension electric light circuit in the New York subways. This was a circuit in One Hundred and Twenty-fifth street, belonging to the Harlem Electric Light Company. The insulation resistance of the cable, as measured just before the turning on of the current, showed it to be 1750 megohms per mile. A test made of the same circuit last week, after one year's continuous service showed it to have an insulation resistance of 1516 megohms per mile. Since the installation of the circuit just referred to, electric light cables of the various types described have been drawn into the subways almost as rapidly as they could be manufactured, and test made of the conductors months after the initial test has

shown them to be in the same electrical condition as when first laid.

There have been several burn-outs in cables in the subways within the year, but with the exception of an abandoned type of cable, to which I shall refer later, these burn-outs have been traceable in every case to defective joints or to mechanical injury. In all, according to the records and best obtainable information, there have been, exclusive of those in the abandoned cable, but five burn-outs in over 185 miles of electric light wire during a period of active service of the conductors ranging from one month to thirteen months.

In the case of 27 out of 34 of the electric light circuits in the subways, not a single defect of any kind has occurred since they were placed in the ducts. There have been several instances where faults not amounting to burn-outs have been discovered by the regular tests which have brought the insulation resistance of certain conductors below the requirements of the rules of the subway, but these defects have generally been located and removed without serious delay to the circuits. Where this has not been the case, it can be fairly attributed to the employment of untried insulation, unfamiliarity with underground service, or to the inexperience of the men to whom the work of connecting up circuits, etc., has been intrusted. For instance, in a number of cases grounds have been traced to contact of the conductor with the lead covering and the linemen so connecting them have explained that they were not aware the lead covering would cause a ground.

On several occasions grounds have been caused by the driving of nails through the lead covering of the cables or leading-in wires, under the molding inside of buildings, and on another occasion a ground was caused by a laborer's pick-ax while excavating for a new subway which crossed an existing subway. It is related of the laborer that when he saw the smoke arising from the burning insulation he first tried to put out the fire by throwing water over the cable and subsequently by throwing wet mortar around it.

It is perhaps not remarkable, in view of all the circumstances, that anything in the shape of an electric wire is looked upon by outsiders with serious apprehensions. It has sometimes been amusing to notice the wide berth given even the leading-in wires used during the making of tests of cables by the occupants of buildings from which the test is being made.

On one occasion, while a test was being made in the basement of the Hotel Brunswick, it happened that the leading-in wires were lying on the floor near by a small pool of water in a hallway. A servant, seeing the water and the wires in close proximity, called out in alarm to one of her companions who was approaching: "Take care, Mary, the electricity is running out."

DEFECTIVE CABLES.

In the case of the cable previously referred to as having been abandoned, the burn-outs were of almost nightly occurrence. The delays to the company using this cable were necessarily vexatious, and I may say that in my references to burn-outs, defects, etc., occurring in underground cables, I have not included those that were due to the use of this seemingly inherently defective cable. This was a lead covered cable with a vulcanite tube as an insulating medium. This special cable has, I believe, been abandoned, and is no longer in service in the New York subways. What may appear a singular feature in connection with the burn outs in this cable was the fact that the cable had a higher apparent insulation resistance than any other cable in the subways, and would frequently, on a test, show an insulation resistance of over 4,000 megohms per mile a few hours before the occurrence of a burn-out. The same cable showed even a higher test at the factory, namely, about 20,000 megohms per mile. In the latter case it was tested with 400 volts. Burn-outs on this cable have occurred when the pressure employed on the circuit did not exceed 600 volts.

The explanation of this may be that owing to the nature of the insulating material and to the fact that it was not tested under water before being lead covered, there may have existed fractures in the vulcanite tubing, or such fractures may have been caused in process of drawing the cable into the ducts. Under the tests made with the 100 and 400 volts E. M. F. of the testing battery, a fault would not develop; under the high electromotive force of the dynamo and the current of 10 or 12 ampères, the fault would develop, perhaps due to moisture of condensation of the air in the tubes caused by the heating of the wire. This explanation is apparently confirmed by the fact that 25 miles of a somewhat similar cable, namely, the Cobb cable, which I have described, but in which paraffine is placed between the lead covering and the vulcanite tube, has been in successful operation in the subways for

high-tension circuits for over two months without any indication of a defect having occurred.

It was rather unfortunate that the cable which I have said has been abandoned as unsatisfactory, and which has indeed been withdrawn from the subways, appears to have been the only cable used for electric lighting purposes in the New York subways which came to the notice of an English electrical engineer during a flying visit to this country, and a description of which cable he presented to our sister society in London in a recent paper, with a favorable prediction as to its probable success.

LOCATING FAULTS.

The method employed for locating faults in electric light conductors in the subways is to test the conductor from point to point until the defect is placed between two lamps or manholes. When a fault is located between two lamps or two manholes, if it is in the cable proper and not in a joint at a hand-hole or box, the defective section is withdrawn, and a perfect section put in its place. With the exception of the hard rubber cable referred to, this has, I believe, been necessary but on three occasions after the current has been turned on the circuit; in two of these cases the defects were caused by improperly made joints. In the other case by a mechanical injury.

In the case of arc light or series circuits, defects in the cables are more readily located than in multiple arc circuits, because of the facility afforded by the openings at the lamps for testing the conductor in sections. In the case of multiple arc circuits there is at present no means of locating faults but by cutting the conductor in manholes. For, as the house connections are made from the cable by T joints, it is obvious that the only effect of disconnecting the lamps or converters from the cable is to separate the two conductors of the circuit. These remarks, it is understood, do not apply to the Edison conductors, to which it is well known access is had at the ends of each pipe by removing the paving and earth above the pipe.

No attempt is made to locate faults in electric light circuits in the subways by electrical measurements, for the reason that the obstacles in the way of obtaining accurate data are so numerous that it has not been considered expedient to rely on the results of such measurements. For instance, the uncertainty as to the distribution of the resistance of the conductor owing to the numerous

joints in the circuit, the variations in temperature of the subways and the difficulty in ascertaining it, etc.

To facilitate the locating of faults, should they occur in the subways, several forms of accessible joints have been suggested for use in the manholes. One of these, known, I think, as the Dillon joint, consists of a metal cup, having in its bottom, apertures through which the cable ends pass. The lead covering of the cable is soldered into the cup, the conductors are connected or spliced, and insulated, and a water-tight cover is screwed over the cup.

Another accessible joint, known as the Cobb joint, is made as follows: A copper disc is soldered on the ends of the conductors to be connected. Over the discs a vulcanite sleeve is placed. Two shoulders having respectively a right and left hand screw are placed, near the sleeve, over the insulation of the conductor. The sleeve is provided with a right and left hand thread. The forward movement of the shoulders is checked by discs on the ends of the conductors Thus when the sleeve is screwed on to both shoulders the tendency is to press the two discs together tightly. This joint can be made quickly, but as to its practical utility it is not possible to speak definitely as yet, since it has not been in actual service in the subways, so far as I am aware. The same is true of the Dillon joint.

It is perhaps a debatable question whether easily accessible joints are desirable in the manholes of subways, as the tendency in such cases might be to lead to accidents by the exposure of live wires.

DURABILITY OF CABLES.

Concerning the much discussed question as to the relative durability of rubber compound and fibrous cables, I do not think sufficient time has elapsed in the case of the cables in the New York subways to enable one to arrive at a definite judgment. In the case of both types of cable, as I have already said, many circuits have been running continuously for over nine months, and in some instances for over one year, without a defect of any kind, electrical or mechanical, having occurred, and the slighter defects that have occurred on other circuits have as yet been so few in either type of cable as not to certainly show any marked superiority of one type over another. Specimens of cable that have been examined after nine to twelve months service show no physical or electrical signs of deterioration of the insulation.

As regards the question as to which kind of cable will best withstand the heat from steam pipes adjacent to the subways, it would appear thus far that the lead-covered fibrous cable is superior to the homogeneous cable *not* lead covered. Lead-covered rubber compound cables have not as yet been tried in the heated districts.

MULTIPLE CABLES.

There are no concentric cables in the subway in this city. The mains of multiple arc circuits are operated in separate lead covers in the same duct. It is contemplated, I believe, by some of the companies to use one lead cover for such circuits hereafter. One objection on the part of the companies to the use of concentric cables is the anticipated difficulty in making joints, especially where frequent connections for distribution are required. This objection should not hold good in the case of the feeder portion of the circuits.

As to the use of multiple cables for electric lighting, one such cable, a fibrous cable, having eight conductors under one lead cover, was placed in the subways, but has not been operated as yet, trouble having been found in making perfect joints. I have no doubt that with the experience since had in joint making, this difficulty would be overcome, but it seems to be the general opinion that the use of multiple cables is not advisable in electric lighting.

On the subject of loss due to increased electro-static capacity or to increased self-induction of conductors in the subways, I may say that I have made careful inquiry of superintendents of stations where the alternating current is used and learn that no perceptible difference in the operation of the circuits as compared with similar circuits overhead is noticeable. I have been informed that in wet, stormy weather a decided improvement is observable—in fact that the condition of the weather does not affect the circuit. This will be the more readily understood when it is stated that a recent test made during the prevalence of a drenching rain storm, of an arc circuit in the subways four miles in length, showed an insulation resistance of 2,400 megohms per mile. The lamp connections were disconnected from the cable proper during the tests, so that all the terminals of the cable were under cover.

JOINTS.

When it was urged upon the electric light companies of this city that they were not using due diligence in placing their wires

under ground, the companies retorted that they were doing so as rapidly as possible consistent with good workmanship, and they cited the fact that it was not possible to joint up the cables more expeditiously than was being done with the number of capable jointers at their command. To this an official of the city replied that this did not, in his opinion, constitute a valid excuse while so many poor men were idle who would be only too glad to be given work at jointing the cables.

This was the view of a layman, but it would seem that in a number of instances in the electric light service in this country somewhat similar views, namely, that anyone could make joints and that any kind of joints might be made, was held by those who should be supposed to know to the contrary.

In this city, I think, it is now fully recognized, by the electric light companies at least, that it pays to employ good jointers in underground work.

Several forms of joints are used on the electric light cables in subways, among them one known as the rubber joint. It is sometimes termed the half marine joint. This joint is made practically as follows: First the lead covering is removed for about 3 inches from the end of the conductor; about one inch of the insulation is then removed from the ends of the conductor; the ends of the conductor are then "sweated" together, a split copper sleeve generally being placed over the ends. When a T joint is to be made a T sleeve is used. This facilitates the making of the joint by dispensing with filing the ends of the conductor, and then wrapping them with small wire. No acid is used in the making of the joint. Resin is commonly used a slag. After the wire has been spliced the insulation is then scarfed for about three-quarters of an inch, when a layer of pure rubber strip is wrapped around the wire spirally, back and forth, about three times, and each time the rubber is brought further up the scarfed insulation. A few layers of white rubber strip is then wound above the pure rubber strip, and after that a layer or two of pink rubber strip. A layer of fibrous rubber tape is then put on over all. Between each layer of rubber strip a small quantity of rubber solution is put on to make the rubber adhesive and practically homogeneous. A lead sleeve is then placed over the joint and wiped on to the lead covering. This joint can be made in about 20 minutes, exclusive of time taken in wiping the lead sleeve. This joint is used altogether on the Bishop and the Safety cables; also

occasionally on the Standard and Cobb cables. But as a rule the Cobb people make a special joint somewhat as follows: The ends of the conductors are spliced in the usual way, a hard rubber ferrule having first been placed over one end of the conductor and a brass ferrule over the other conductor above the insulation. A machine like a double vise is then placed over the lead covering of the cable and made fast thereto. A tightening device next draws the ends of the vulcanite together, taking up slack in the cable. The vulcanite sleeve or ferrule is then welded by heat to the vulcanite tube, after which the brass ferrule is drawn over the tube. A mould is then placed around the joint into which molten lead is poured, thus casting a solid lead sleeve. This is quickly cooled by the application to the mould of cold water. The mould is then removed and the joint is complete. This form of joint has been found satisfactory, I believe, and it is claimed that it can be made in much less time than a half marine joint.

The joint chiefly used on the Standard Underground Cable is made differently from either of the foregoing. After the conductor has been spliced as usual, and the lead covering has been cut back from the insulation, a few turns of tape is passed around the splice. A leaden sleeve is then put on over this and wiped firmly to the lead cover of the cable. When this has been done two or three small holes are punctured in the leaden sleeve through which a boiling insulating compound used in the manufacture of the cable is poured, filling up the sleeve completely; after which the holes are closed by solder. These joints have been found to give excellent service in this form of cable. The time taken in making this joint is about 30 minutes.

LEAD COVERED CABLE.

The cables used in the electric light service in the New York subways are, as I have elsewhere stated, without exception, lead covered. In the case of fibrous insulation, this is essential to exclude moisture, but not in the case of the rubber cables, except as a protection against gas and acids, and to a certain extent, mechanical injury. The use of this lead covering is not required by the subway rules. In addition to being a protection against the attack of acids and gases, the lead covering is considered a safeguard against accidents to men working in the manholes among live wires. For, in the first place, if a defect should occur in the insulation in the manhole, the presence of a ground fur-

nished by the lead covering would make the defect known at the regular test, which, if the defect were of a serious nature, would insure its being located and eliminated. Whereas, if the conductor were not lead covered there is a probability that a defect in the insulation might occur that would not be indicated by the test, but which might expose the conductor and render it possible for workmen in the manholes to make contact therewith. It would be quite possible for a workman to handle the lead covering of even a defective conductor without injury since the lead covering is grounded throughout the length of the subway.

It will hardly be credited by some people, but it is a fact that live electric light wires conveying alternating and continuous currents for arc and incandescent lights are handled and moved about in the manholes by means of the lead covering without the slightest indication that such wires are alive. Indeed, it is quite a common occurrence to start up such circuits immediately after a rubber joint has been made in order to save time and then to have the plumber adjust and wipe the sleeve on the lead cover while the circuit is in full operation.

Another fact is this, that in the subways no shocks whatever due to induced currents in the lead covering are felt by the workmen in handling the lead covered cables conveying the alternating current. It is quite conceivable that such shocks might be noticed, as I believe they are, where the cables are suspended from point to point and insulated. In that case any one handling the lead covering of the conductors would doubtless receive the accumulated induced charge.

It has been stated frequently that such induced currents, where the lead covering of the conductors is insulated, have been known to injure the lead covering and eventually to destroy the insulation.

So far as I have been able to ascertain, not in a single instance has such an action taken place in the subways.

As a matter of fact close personal observation and careful inquiry on all sides have failed to discover thus far any sign of deterioration in the condition of the material of the conduits, the lead covering of the insulation, or of the insulation of the cables in the subways, with the exception of the effect upon the lead covering of the telephone cable in the creosoted wood conduit referred to. I may add that even in the latter case, personal investigation and inquiry made of workmen have not confirmed

the statement that the lead covering has been attacked. At all events there is no evidence of any such wholesale manufacture of white lead as has been reported from other places where lead covered cables have been placed in creosoted wooden boxes.

INSULATION AND TESTS.

The requirements of the rules of the subway company, as regards insulation, are such that none but a first-class insulation can well be employed on the conductors assigned to high potential arc and incandescent circuits. These rules require an initial insulation resistance of 15 megohms per mile per 100 volts electro-motive force employed on the circuit, and a minimum of five megohms per mile per 100 volts. The initial test is made when the conductor is first laid in the subway, and prior to the turning on of the current. The minimum requirement is allowed after the circuit has been in use. This insulation requirement refers to the conductor proper in the subway, and does not include the lamps, aerial connections or converters. The rule does not apply to circuits of less than 100 volts E. M. F. In the case of alternating circuits, the uniform electromotive force employed in this city being 1,000 volts, the conductors to be employed in this service are required to show an initial insulation resistance of 150 megohms per mile, and a minimum insulation resistance afterwards of at least 50 megohms per mile.

The average E. M. F. of the arc light circuits in the subways is about 2,000 volts, but in some instances it runs up to 3,500 volts. In the latter case the initial insulation resistance required by the rules is 525 megohms per mile; minimum, 175 megohms per mile.

It was at first thought by many that it would be impossible to maintain even the minimum insulation resistance required by the rules, and this supposed impossibility was cited by some of the electric light companies as an instance of the impracticability of the proposition that they should utilize the subways. The representative of one such company very naively stated that it would certainly be impossible for his company to maintain this insulation if compelled to go into the subways, as the insulation his company used in its service was underwriters'. One of the experts of the same company, in his evidence, repeated the very common remark that one megohm, *if it could be maintained*, would be quite sufficient for practical purposes. I do not think

this statement will be seriously contradicted, but the difficulty is to maintain the insulation resistance at one megohm in practice. Experience in the New York subways has shown that it is vastly easier to maintain the insulation resistance at 150, and even 500 megohms per mile than it has been in the past in other cities to maintain it at one megohm per mile. A gentlemen writing of the Chicago underground system, not quite two years ago, remarked: "It was found that although the insulation measurement of the lead covered cables in the conduit was very high, considerably above a megohm, a short circuit would form generally within 1,000 feet of the station between the two sides of the circuit."

The explanation for this short circuiting under such conditions would appear to be simple, namely, that if the insulation resistance of a conductor is but one megohm per mile, the covering being of the ordinary thickness, it is clear enough that it is decidedly inferior insulation; and if the normal insulation resistance of the conductor is very much higher than one megohm per mile, but the measurement nevertheless shows it to have an insulation resistance of but one megohm, it is or should be sufficient evidence that a fault has developed in the insulation which need surprise no one when it produces a short circuit or burn out.

As I was in no wise responsible for the promulgation of the subway rule which places the initial and minimum insulation resistance of the electric light conductors at the figures given, not having been connected with the company in any capacity at the time the rule was authorized, modesty need not restrain me from saying that experience of over a year has amply proven the wisdom of those requirements. For these requirements not only necessitated the use of an insulating material possessing high specific insulation, but also compelled the exercise of the greatest care in the details of placing the conductors in the conduits, in the making of joints, etc.

When it is stated that these conductors are jointed at every manhole, and in many instances at several places between manholes, the need of such carefulness in order to maintain a high insulation will be understood.

If, for example, the method of making joints that it is related was employed some years ago in Philadelphia—namely, to strip the ends of the lead covering for two or three inches and then to place three or four turns of tape around the ends of the conductor—had been followed in the New York subways, and had

been permitted in the absence of the rules referred to, I think no doubt I would have had to report to-night a continued series of failures in the electric light service similar to those so often quoted as having happened in Philadelphia. I am confirmed in this belief by the fact that the first electric light conductors laid in the New York subways were found to possess an insulation resistance of but little over 100,000 ohms. This, notwithstanding that the insulation resistance of the conductors at the factory was over 2,000 megohms per mile. There were about 40 joints in these conductors. When these had been cut out and new ones made by an expert jointer the insulation resistance rose to over 1,500 megohms per mile, and a very recent test of the same circuit shows it to possess virtually the same insulation resistance.

Under the methods once in vogue in other cities in this country with regard to underground work, in which no tests for defects were made excepting for such as would be indicated by an ordinary magneto, the circuit I have referred to would have been put in operation without question, and there is, I think, not much doubt as to what the outcome would have been.

The high tension electric light conductors are tested weekly for insulation resistance. The tests are made by the direct deflection method, a Thomson reflecting galvanometer being used, and as a rule a 100-cell chloride of silver battery is employed as a testing battery. The tests are generally made from some room or basement adjacent to the terminals of the conductors in the subway, in order that the subway portion of the circuit may be tested exclusive of aerial portions.

At present the subways do not extend to the electric light stations, although in a very short time they will do so in the case of the Stanton Street United States Illuminating Company's station.

Where the conductors emerge from the subways they are run through subsidiary iron pipes up the side of a pole. From this pole the testing leading-in wires are run to the testing room.

The subway conductors are as a rule tested exclusive of arc lamps, converter and inside wiring, but frequently also the tests are made inclusive of arc lamps and converters. These latter tests are only accepted when the results fairly indicate that the decreased insulation resistance is due to the lamps or converters. In quite a number of cases the tests with converters included show an insulation resistance up to the requirements.

Tests of circuits are not made inclusive of house wiring, because of the generally low results of trial test. Some such tests that I have made showed an insulation resistance of the house wiring of less than 1,000 ohms.

The following record of actual tests may be of interest:

Circuit A, Arc. Initial test 588 megohms per mile. Last test of same circuit 388 megohms. Present length of circuit 9.5 miles.

Circuit B, alternating. Initial test 141 megohms. Last test 1,250 megohms. Length 9.6 miles The first test was made when circuit was much shorter than at present, and doubtless, the terminals of conductor were exposed during that test.

Circuit D. Initial test, Jan. 6, 1889, 424 megohms per mile. Length of circuit, two miles. Subsequent test, Jan. 2, 1890, 484 megohms per mile.

Circuit E. Jan. 4, 1889. 1,750 megohms per mile. Same circuit, Jan. 4, 1890, 1,516 megohms per mile. Length, 1 mile.

Circuit F. July 7, 1889, 264 megohms per mile. Jan. 3, 1890, 343 megohms. Length, 6.6 miles.

The readings for these tests are generally taken after one or two minutes' electrification.

Tests with converters included in some cases show very fair insulations. One circuit with 34 converters included showed 11 megohms total insulation resistance. Another with 11 converters included gave a total insulation resistance of 159 megohms. It is not uncommon to get an insulation resistance of from two to five megohms with 30 and 40 converters in circuit. The foregoing tests did not include aerial portions of circuits. It should be said that the insulation of the converters and connections is being constantly improved, and, in my opinion, the time is not remote when the underground circuits will test up to the present requirements of the subway rules at all times with converters included.

As all of the conductors of the same company do not terminate at any one point, and the testing instruments have to be moved from place to place, the apparatus used is of a portable pattern. The entire outfit can in an emergency be carried by one person, and very readily by two persons.

Contrary to the expectations of some people, the actual making of these electrical tests has not been attended with any serious difficulty. The most troublesome factor has been that due to

surface leakage at the battery or other parts of the testing equipment, during the very humid weather, which prevailed so continuously last summer and winter.

The time for making these tests is as far as possible chosen to suit the convenience of customers. The majority of the tests are now made in the early mornings. All circuits are tested once a week at least.

About 130 miles of the subway electric light conductors referred to are employed as carriers of alternate current for incandescent lighting. About 60 miles as carriers of arc light, and incandescent continuous currents. The circuits vary in length from one mile to eleven miles; the longest arc light circuit is 10 miles in length; the longest alternating circuit is 11 miles in length. In ten miles of alternating or arc circuit there are from 450 to 500 joints. The greatest number of converters on one subway circuit is 65. There are 14 arc light circuits and 25 alternating circuits in the subways.

Quite recently an alternating arc circuit has been installed in the subways which is intended to be the pioneer of numerous such circuits. I may say that it is ultimately intended to operate at least 125 arc lamps in such circuits.

LIGHTNING ARRESTERS.

In the case of many of the electric light circuits that were first laid in the subways of New York city, lightning arresters were used at street lamps and at the terminals of the cable, and in a number of instances the same apparatus is still used. These "arresters" are those known as the Acheson cable protector, and are intended to protect the cable against disruptive discharges from any source. The principle upon which the device is intended to act is that the disruptive discharge, or what would be the disruptive discharge, will jump the air space between the points of the needles, thus relieving the cable from the strain. The utility of this device for the purpose intended has yet to be demonstrated in this city, inasmuch as the frequency of burn-outs in unprotected cables in the subways has been no greater than in those which are equipped with the protector; the percentage of burn-outs on cables in either case being, as I have before intimated, very low. It is as yet, I think, an open question whether the use of this or any equivalent device is necessary. There is no record of any of the cables in the New York subways having received injury from lightning during the past year.

It is commonly supposed that the freedom from burn-outs which the successful electric light cables in the New York subways have enjoyed, as compared with the earlier experience of other cities, is due to an increased thickness of insulation around the conductor. This may be the correct explanation, but it is worthy of attention in connection with this subject that certain electrical condensers have for years been placed in positions where they are exposed to the full effect of lightning discharges on telegraph lines, without in a single instance having sustained injury therefrom. Similar instruments have also been placed across the poles of 1,000 volts alternating dynamo machines for days without perceptible harmful effect. Since it is difficult to imagine a better opportunity for a disruptive discharge to effect its escape to earth than that presented by the extremely thin tissue paper used in those condensers, the thought is suggested that if this paper can be so constructed as to act as a barrier to the passage of such charges there may be more to be considered in this matter of insulation than the mere question of thickness of the insulating material.

ALLEGED DANGERS OF THE SUBWAYS.

The dangers to be apprehended from the existence of the electrical subways and from the placing of the high-tension electric light currents therein, according to those who are perhaps more or less inimical to that action, are varied. In general terms, they say that the dangers which menace the public and employees from the presence of wires overhead will be multiplied manifold when the wires are underground. But, when asked to specify those dangers, the reply is limited to the following, namely: first, that linemen will be killed by coming in contact with live wires in the manholes; second, that the "powerful" currents will leave the subways and enter buildings by way of water and gas-pipes, etc.; and, third, that accidents due to explosions of gas in the subways will be numerous.

As regards accidents to workmen in the manholes, due to contact with live wires, no one will say that such occurrences are impossible, but inasmuch as not a single accident of this kind has occurred in New York City, or so far as I can learn, elsewhere, in electrical subways, it is fair to assume that, with the exercise of proper supervision of the wires, this is not likely to prove a frequent source of accident. I was present at the inquest on one of the unfortunate linemen who was killed last year in New

York City by contact with an overhead wire, when a witness who had just made the statement that he apprehended more accidents from the placing of wires underground than had occurred overhead, was asked if he was aware that there were at the time about 100 miles of electric light wire underground in New York City assigned to high tension circuits, and that not one accident had thus far occurred in the manholes; to which he replied that this state of things was explainable in his opinion by the fact that the electric light wires underground constituted but one-tenth of the electric wires of the city, and that when all the wires were underground the accidents in the subways would increase in the same proportion; which reply caused the foreman of the jury to remark that the public would probably not complain of an increase of accidents from nought to 10 times nought.

I have already suggested in another place that the fact of the wires being metallically covered may have conduced to the immunity from accidents which the workmen in the manholes have enjoyed. I may interpolate here that it is recognized that the efficiency of the manholes would in many instances be increased if they were larger, and wherever the surrounding condition of the street will permit, it is, I believe, contemplated to enlarge the manholes.

So far as the statement is concerned that danger is to be apprehended by the entrance of powerful currents into buildings by way of water and gas pipes, by contact of a grounded conductor in the subways, it would scarcely be worthy of notice before a body of electricians, but for the persistency with which it is said to be urged by men of prominence in the electrical profession. It is conceivable that if a conductor, within a building, should by accident come in contact with a well insulated gas pipe also within a building, one might receive a shock by contact with the gas pipe if in some manner he should complete the circuit, but in what manner, in the event of a ground in the subways, any dangerous current can be conveyed to the inside of a building by means of gas and water pipes which have the entire area of the city's foundation as a ground or return circuit is more difficult to understand.

But whatever may be the dangers, stated and unstated, so freely predicted as liable to occur with the wires underground, it may certainly be said that with the electric wires underground men will not be injured by falling off poles in the subways.

Wires when in the subways during the prevalence of sleet storms, etc., will not fall upon people or horses in the street, nor be torn down by elevated railway trains, street cars, etc.

GAS IN THE SUBWAYS.

In my opinion the presence of gas is the most serious defect of the electrical subways in cities; of course it is not an inherent defect in the subways, but it is nevertheless a very troublesome one, not only because of the danger of explosions therefrom, but also because of its ill effects upon workmen employed in the subways.

As previously remarked, the ducts used in the subways are not only joined together as nearly hermetically as possible, but, except in the case of distributing ducts they are laid in a solid body of cement from manhole to manhole. It is supposed that the gas obtains ingress to the manholes through the place where the iron manhole cover rests on the masonry of the manhole. But at whatever point the gas enters the subways, its unwelcome presence is acknowledged, and while it is self-evident to any one who will investigate the matter for himself, and is actually admitted by the gas companies that the gas emanates from the gas mains in the streets, nevertheless the subway engineers have been constantly at work devising means to remove the intruder.

To this end various methods for ventilating the subways have been suggested and tried, the most successful of which thus far has been the ventilation of the subways by the use of blowers stationed at intervals along the subways, and arrangements are now in progress to place fifteen such blowers in operation to cover the entire subway system.

As the ducts become filled with cables, however, the free passage of air through them is prevented, and in this way the utility of the blowers is diminished. In order to evade this difficulty a six-inch wrought-iron pipe has been laid above the subway ducts in the more recently constructed subways. This large iron pipe has openings at each manhole. The openings are graduated as to their extent as they recede from the source of the air pressure. The larger openings are at the points remote from the blower. It is intended by the use of these large pipes to furnish a counter-pressure in the subways somewhat exceeding any tendency of a pressure from the outside—rather than to produce a strong current of air through the ducts, and in this way to prevent the ingress of gas through any crevices that may exist in the subways.

These air pipes are shown in the drawing, Fig. 5, to the right of the distributing ducts.

It has been frequently suggested that good results might follow a suction method of ventilation, but experience has shown that this would rather aggravate the evil, as it would draw into the subway all the accumulated gas in the streets besides inviting a large leakage from the gas mains.

The only beneficial effect to the subways of this resort to blowers to drive out the gas is that the air dries up the ducts and manholes within quite a distance of the blowers.

The cause of explosions in the subways has not in every case been definitely located. It is of course known that they are due primarily to the ignition of an accumulation of illuminating gas mixed with atmospheric air in the explosive proportions, but the difficulty has been to ascertain by what means the gas has been ignited. It is on record that these explosions have occurred in sections of the subways in which there were at the time no wires whatever. And in cases where there have been live wires in the vicinity of an explosion, tests made immediately after the event have shown that those wires were in practically perfect condition as regards insulation. There are but three instances on record in which a defect in an electric light cable has occurred simultaneously with an explosion in the subways, and in one of these cases the defect occurred so nearly incidentally with the explosion that while it is quite possible that the defect may have caused the explosion, it—the defect—may have been due to mechanical injury due to the explosion.

Among other theories it has been suggested that the gas may be ignited by currents induced in the lead covering of alternating current conductors. This might be the case if, as I have before suggested, the cables were supported from beam to beam, as on a bridge, on insulated stands, and if the lead coverings only approached each other at intervals; but where the lead coverings of the conductors are not only grounded throughout their lengths as in the subways, but are also joined metallically, in fact are practically one cable in the ducts, it seems unlikely that a quantity of induced electricity, sufficient to produce a spark, could be accumulated at any one point.

In the case of at least two explosions in New York City, the evidence showed that the gas in the subways had been ignited by a lighted lamp or match in the vicinity of some subsidiary duct

connecting with the subways. In other instances by a match or lighted cigar thrown in a manhole. It is known that in Chicago an explosion was caused in the subways by a live coal from a passing fire-engine falling upon the cover of a manhole.

With but one or two exceptions the explosions have not injured the cables in the subways, which is probably due to the small and round surface which the cables present.

It has frequently been suggested that if solid ducts were employed instead of tubular ducts, these explosions would be avoided. While this would be, if correct, a strong argument in favor of solid conduits, that is, ducts in which the conductors are not removable, notwithstanding the generally admitted fact that such ducts are not practicable for subway work on a large scale, experience has demonstrated that explosions have occurred repeatedly in manholes and in small junction boxes of subway systems in which there were no hollow ducts.

I may add that, pending the installation of blowers in certain of the subways, men are employed day and night opening manholes to permit escape of gas.

I had intended to comment briefly on the comparative expense of maintenance and reliability of underground wires in cities as compared with overhead wires, but as my paper has far exceeded the limits which I had placed upon it, I shall leave that and other features in abeyance for the present. Perhaps something bearing on those points may be brought out in the discussion.

The following are some of the rules of the subways of New York City which have been promulgated as precautionary measures or as a result of actual experience.

No bare ends or bare portions of conductors, whether in or out of service, are permitted in the manholes. Every conductor in the manhole is treated as though it were operative.

No joints, except such as are protected by a metallic covering, are permitted in the manholes.

No exposed lights or fires are allowed in manholes.

All conductors in manholes are required to be arranged symmetrically around the walls and to be plainly tagged with the designating mark of circuit and the name of the owner. One of the pictures which I have, by the courtesy of Mr. Beckwith, the Chief Engineer of the Subway Company, been able to procure from his office, shows the cables passing through the manhole in rather a haphazard way. This would do where there are but one

or two conductors in the conduits, but when the conductors multiply, an orderly arrangement of them is essential.

No switch boxes are allowed in the manholes. The reason for this is that, in the first place, a switch box for each company would take up too much of the limited room; and secondly, in the case of electric light circuits, it is feared that attempts to change live circuits might produce dangerous sparks in the manholes.

In conclusion, I think it may be said that the experience derived from the practical operation of the electrical subways of New York City has either made apparent or confirmed, among other things, the following:

That it is possible to successfully operate all classes of electric conductors underground in cities.

That at least for conductors conveying high-tension currents underground it is advisable to set the standard of insulation high.

That regular insulation tests of the conductors are very valuable.

That liberal thickness of insulation is desirable for high-tension currents.

That it is unadvisable to place underground new types of cable or insulation until they have been subjected to tests and conditions analogous to those to which they will be subjected underground.

That for electric light conductors — especially distributing mains — many conductors under one cover are not advisable owing chiefly to the difficulty in making joints in such cables.

That all sharp edges in ducts should be avoided.

That until the gas light companies are required, like the electric light companies, to maintain their mains in a fairly sound condition underground, a means of ventilating the subways should be provided simultaneously with the construction of the subways.

And lastly, that while other features may be accessories thereto, the employment of smooth, strong conduits, accessible ducts for distribution of the current, first class insulation, constant expert attention to details and thorough organization in every department, are essential to the production of a successful electrical underground system.

DISCUSSION.

THE CHAIRMAN (Vice-President T. C. Martin):—I am sure we must feel extremely indebted to Mr. Maver for the very able and massive paper that he has presented to us this evening. It is a magnificent aggregation of data. And while we may not take the roseate and optimistic views that he does of the situation, we must feel that he has endeavored to present to us a truthful picture of the subways of New York City, as he knows them to-day. We shall now be very glad indeed to have a discussion of this paper; and I would like it to be as expeditious as possible, as the evening is already advanced.

MR. CHARLES CUTTRISS:—There is one question I would like to ask of Mr. Maver, that is, if any great drop in insulation has been noticed between summer and winter. As you know, we have in the Commercial Cable Company a straightaway line of some 12 miles under ground. The major part of that is gutta-percha. Four miles of it is the Standard lead-covered cable. The insulation of that circuit in January is generally the greatest and is about 1,000 megohms. In summer it drops to about 300. That is also observable in our sea cable between Wall street and Coney Island. That is a better line, and the drop there is from about 1,400 to 300. As most of the compounds used in the subways are either India-rubber or fibre, and as ours is gutta-percha, I would like to know if Mr. Maver has any data which bear upon that.

MR. MAVER:—As a matter of fact the results have shown a higher insulation of the cables since the approach of cold weather; and also in the case of new cables. But whether that is due to the cold weather or to improved methods of making the joints and more experienced workmanship, is a matter which I think another winter would have to disclose. I have, in speaking of the matter of an increased insulation noticeable at different times, thought that perhaps it was due to lower temperature, but I do not think there is as yet sufficient data to enable us to speak definitely on that point.

MR. CHAS. G. CURTIS:—I would like to ask Mr. Maver if he has any approximate estimate of what the subways in New York have cost so far per mile?

MR. MAVER:—I think about $3,000 per duct per mile. I am not positive; but I think I have heard that statement.

MR. CURTIS:—Can such ducts as they are now laying be built on the average for something like $3,000 per mile?

MR. MAVER:—I do not know positively, I did not speak by the book. I have heard that figure mentioned, I think. It may be four or five thousand.

THE CHAIRMAN:—I see Mr. Lauterbach here. Probably he can give us that information.

MR. EDWARD LAUTERBACH:—Of course, the cost depends very much on the number of ducts in a trench. To dig a trench and

lay the concrete, and have only one or two ducts, will cost very much more per mile than it will with eleven or thirteen ducts. The precise average has not been ascertained, I think. But the figure that Mr. Maver mentioned may be looked upon as a minimum—the average cost per mile per duct would not be less than $3,000, and probably exceeds that amount.

Mr. Joseph Wetzler:—Mr. Maver in his opening remarks stated that many people thought the underground system in its ideal form should be a tunnel, which could in the first place contain all gas, water and other distributing pipes, and in addition the electric wires; and frequently Paris is held up as the ideal. Now, as a matter of fact, Paris having that ideal system of sewerage and about to go into electric lighting, does not propose to use it at all for the purpose of distribution; and I think his remarks in controverting that idea very apt. Indeed, in Paris to-day, instead of the sewers being full of wires, as many people suppose, there are probably not more than two electric light high-tension circuits. These were laid about ten years ago, and are still in operation, but none have been laid since. Where they are going into distribution to-day, they are actually using ducts which are built under the sidewalks. So that they have come also to see that the large sewer system is not what it appears to be as a system of distribution.

Mr. W. J. Hammer:—I would like to ask what proportion of electric light wires in the subways are at present live wires?

Mr. Maver:—Well, I presume, perhaps 95 or perhaps 99 per cent. I do not think there are over 10 miles of electric wires in the subways to-day that are not in active operation. If they are not in use it is simply because they have been recently laid, and are in process of being connected up.

Mr. Hammer:—I would like to ask also if these wires are connected with the overhead system? I presume, in the case of the Stanton street station, for example, that the wires run overhead some distance from the station before they go into the subways.

Mr. Maver:—Yes; that is true. They must necessarily go into the stations by overhead wires. The subways do not extend to the stations.

Mr. Georges d'Infreville:—I wish to supplement what Mr. Wetzler has said about the system used in Paris, which is perfectly correct. They do not use any insulation at all on their wire. In fact, they do not use wire. They use bars of copper, which rest on porcelain insulators. This system is, however, not used as yet to any great extent.

The Chairman:—There is one gentleman present whom I think we should hear from. I know that his native modesty keeps him quiet; and I can understand that there are other reasons why he is not particularly anxious to speak. But his work has been extensive, and so much greater than that of any

one else in connection with the subways, that as one of our members I think he might give us an idea as to his opinion of the results that have been obtained. I refer to our highly esteemed and highly respected member, Dr. Wheeler. I think that Dr. Wheeler has had an ordeal that very few of us would care to go through. And I think that he has come out of it with credit to himself, and that is perhaps more than could be said of a great many who were subjected to such conditions as have prevailed in this city under the regime of the Board of Political Control.

DR. SCHUYLER S. WHEELER:—Mr. Chairman, unfortunately I arrived here just as Mr. Maver was concluding, and I am not acquainted with the matter contained in his paper, and therefore, I hardly feel prepared to say anything on the subject. I feel that the matter of testing underground wires has been in the very best possible hands, and so I have not given as much attention to it as I might otherwise have done. My duties have been confined to the examination of overhead wires and perhaps their condemnation, and I do not know that I can add anything to the subject of wires underground. If there are any questions that anybody would like to ask me about overhead wires, I should be very glad to make an effort to answer them.

MR. WM. B. HALSEY:—I would like to ask one question—has there been anything in the plans of the New York subway system looking toward the distribution of district circuits? I refer, of course, to the messenger telegraph.

MR. MAVER:—I presume they would be distributed in the same manner as the telephone and telegraph circuits. It is open to the district companies to avail themselves of these methods. That is, they would branch off from the manhole with their cables to the buildings where they have their district boxes.

MR. HALSEY:—The reason I ask the gentleman is, because, generally the district companies put in their boxes free of charge to the subscriber; and the consequence is that the general cost of anything of that kind would be a serious question. What I was getting at was whether the regulations of the subway system would allow such a thing, or whether they would have to put a special main in for each house?

MR. MAVER:—I think I have stated in my remarks concerning the telephone and telegraph that the plan adopted was to run the cable in the subways to the manhole adjacent to the building or block of buildings where it is desired to made connection with the customers. Precisely the same plan, I should think, could very readily be followed by the district messenger companies.

In the first part of my paper, to which Mr. Wetzler has alluded, I assumed that a tunnel system would be the most satisfactory if the cost were not beyond all bounds; but it had occured to me that even if we had such a tunnel on one side or in the middle of a street, there would still remain to be furnished a distributing system. You would either have to pass from the tunnel in the

middle or sides of the street or at street corners from manholes, as we do at present. But certainly, in addition to the tunnel, there would necessarily be for proper distribution, especially of electric light currents, a distributing system such as is at present employed above the regular or trunk line ducts. That, of course, would add greatly to the cost of the tunnel.

THE CHAIRMAN:—I see several gentlemen in the audience who are connected with arc lighting companies in this city. I should imagine that they would have some sentiments to express on such an occasion as this.

I have noticed that very often when we have a very important paper, one which we think will elicit the most valuable information, it sometimes fails signally of its purpose. For some reason or another we seem half afraid of it. We have before us such a paper this evening; but I would not like to have the meeting close without expressing my own belief that in these subway matters the companies which have been running their lines overhead to the present time have at least something to be said on their side; not so much by way of extenuation or excuse, as by way of explanation. Eight or ten years ago, to go no farther back, none of us expected that this electric work in New York City would be done for a long time to come by other than overhead wires. In fact, there was no desire expressed anywhere by anybody for anything but overhead wires. We had then simply the telegraph and allied services. If the overhead wire was not run to furnish some new service, the public grumbled until that wire was run. I think nobody can deny that. Then we had the telephone, and everybody who could afford it wanted telephonic service. The question of having these telephone wires run underground did not enter into the question at all. The only trouble was the price of the telephone service. Then we come down to the period of the electric lighting systems and their introduction into this city, a period of about a decade. Most of you who were present in the city at that time know that there was not the slightest call when the electric wires were first introduced into this city for putting them underground. Everybody said, let us have the electric light, it is a good thing, and the wires were strung overhead. On some thoroughfares, such as the Bowery, for example, they were plastered up so thick that everybody wondered whether the daylight would ever have any show again.

There was very little question as to insulation. The companies, I think, did the best they could. They were pioneers. They were not particularly well instructed in the matter. In fact, I do not think any of us were; and as pioneers, I think those early companies, some of whose work remains with us to this day, are at least entitled to our respect, even if we have to regret their mistakes. Just as long as our pioneers in America remain our glory and our promise for the future, I do not think that we

have much occasion to find fault with those who are pioneers of electric lighting in this city, and therefore practically in this country. I recollect some years ago the Marquis of Salisbury ran wires through his garden, and in so doing killed his gardener. I am not aware, however, that the press of England has yet used that incident as the ground of a clamor for deposing him from his position as Prime Minister, or has alluded to it in any way as derogatory to his personal and private character. Had he, however, been connected with an electric lighting company in the city of New York, I dread to think of the things that would have been said about him; of what indictments he would have labored under. As Mr. Maver has told us this evening, the electric lighting companies, when the increase of the wires led to a public call for their being under ground, were offered the choice of any number of systems, and I know that in a great many cases throughout this country a large number of the electric lighting companies put large sums of money in subway work, all of which inside a year had to be written off to profit and loss. It need not be wondered at that companies with such interests at stake desired to go slowly and with fifty or a hundred systems presented to them, each the best and the others all the worst, it is not, I say, to be wondered at, that each company wished some one else would try the experiment first. We all know how the early subway work in connection with the electric lighting in this city failed. As I listened to Mr. Maver's description of that this evening, I was reminded of an incident told me by a fellow journalist a short time ago in connection with the yellow fever epidemic in the South. A young man there who was quite interested in Free Masonry, told his friends that when he died he wished to be buried in regalia. There were very few of his friends left by the progress of the epidemic, and the sad duties were left to an old negro who was told to go to this man's wardrobe and take his regalia and put it with the deceased in his coffin. It happened that this young man, while a Mason, was also a prominent personage in connection with the Mardi Gras festival, and had distinguished himself at the preceding festival by wearing a peculiarly brilliant and fantastic harlequin costume. You may, perhaps, imagine the consternation of his friends, two or three weeks afterward, when, looking over the young man's effects, they found the Masonic regalia—the harlequin costume was gone. Now, gentlemen, it may seem a false parallel, but the electric wires of this city deserved to be buried in a decent, respectable manner, instead of which they were sent before the great white throne of public opinion in what I may speak of as a harlequin costume. Within the last year, however, there has been an improvement, and I think none of us can gainsay the statement that Mr. Maver has made, which shows that at least the pioneer work of the subways is at the beginning of its end. We have gone through the overhead period for some eight or ten years, and now

I think we may perhaps have a pioneer period of eight or ten years in the subway work. But we are getting there. I think all who are interested in the welfare of this business are interested in seeing the wires put underground, if they can be made to work successfully. Mr. Maver has shown us this evening how far the work can be accomplished, and I think it may be safely said that in the subway work of the future all those engaged in it will have the heartiest and best wishes of the American Institute of Electrical Engineers.

If there be no further business I would like to state that I have been asked by the Entertainment Committee of the New York Electric Club to mention that on Thursday evening Mr. Grosvenor P. Lowrey, a well-known lawyer of this city, will read a paper on the subject of patents and their relation to inventors. Any gentlemen who are interested in the subject the Entertainment Committee will be very glad to have as their guests.

I would also like to announce that our subject for the March meeting will in all probability be the Westinghouse tests at Johns Hopkins University. We all know the unimpeachable reputation of that university in such matters. But even if we did not, I think it would be sufficient to say that the paper will be brought before us by our Vice-President, Dr. Louis Duncan. That paper will probably be read in March. We have another matter on the programme for March, but it will probably be carried over until very late, or even into April; and that is a lecture at Columbia College by the kind invitation of its officers by Prof. Elihu Thomson on the phenomena of alternating currents, with experiments. I have no doubt that our President will give us a royal evening on that occasion.

Mr. James H. Seymour:—I am not a member of this organization. I do not know that I have a right to speak; but I do want to raise my voice in defense of the electric industry against the public howl which is brought forward in the daily papers. They think it is incumbent upon them to abuse every man in official position, and every one who is developing the electric industry. I have no remembrance of any industry ever meeting with the obstruction and with the abuse that the electric light business has met with in this city at the hands of the press. The press of New York has not been fair. Why it has not been I am unable to understand. I am aware that the citizens became annoyed with the numerous overhead wires, and wished that they might be buried; and from that howl, and through different commercial organizations they went for the wire question. The press has simply jumped upon the electrical industry and injured it to the amount of many millions of dollars in the United States, and has impeded its progress. I think those who are connected with it as an industry have a right to demand that we shall have fair play and the opportunity to build a subway and to take care of the wires overhead, and if by carlessness on the

part of the companies people are killed, they are financially responsible, and let the responsibility rest where it belongs. Because there is an accident from the overhead wires, it is not just to require that the lights must be shut off as has been done in this city during the holiday season, where merchants have lost thousands of dollars in trade. At this point I would like to ask, as Doctor Wheeler invited questions about the overhead wires, why it is that insulation has improved so much in the last few days, from what it was when they were chopping the wires down so recklessly. Perhaps the gentleman can tell us about that. He, I presume, has come in for his share of abuse, and I am ready to defend him when it is required.

DR. WHEELER:—I have been out of town during the last week.

THE CHAIRMAN:—I think we ought to be extremely glad that Mr. Seymour is with us this evening, and has had the courage to speak on the action of the press in the manner in which he has. He said not a word but what was strictly true Our industry was treated in the manner that he describes, but the industry will survive, and I have sufficient respect and confidence in the great journals of New York City to know that they will be with us. Their own future forbids them being against us.

DR. WHEELER:—As the subject is rather serious, I think I had better make a more careful answer to the last question. As I understand the question, it is this, Why have the companies found that within the last week their wires are safe enough to light up, while before they were not safe enough? Well there has not been any difference in the safety of the wires, but from the time that they have been shut down, some months ago, the companies have been unwilling to take the risk of running, because they were ordered to discontinue the use of their wires until the electric adviser of the subway commission would certify that the wires were safe. Of course, I do not think anybody would undertake to go into the insurance business for all the wires in the city, and therefore the wires have not been declared safe. The companies were informed that the wires would all be examined as rapidly as possible, and that it would be necessary to examine them very carefully inch by inch; and that as soon as any wires were found that were safe the companies would be notified. The companies then, after talking the matter over, decided to go ahead and try to make some wires safe, and they came to the Board of Electrical Control and asked that some wires which they thought were pretty good should be examined. These wires were examined, and after going over them for a very small part of the whole distance a number of features about the wires were found which could be improved; that is, improved in an essential respect, and the companies were informed that as the resolution of the board required that the wires should be declared safe, it was not reasonable to expect that those wires would be declared safe as long as they were in a condition that could obviously be improved. The companies then said that they did

not think that they could bring them into such a condition; that the changes required were not such that they could bring about, and they stopped work for awhile Within the last few days they have evidently made up their minds that they would take the responsibility of running their wires; and they have started up one of their stations, and lighted certain lamps. A good many of them are using their cables which they put in the subways, some of the cables being put in since the lines were cut down, but the companies are simply going ahead and taking the risk themselves, which I think they are quite sensible in doing. Before, they were not willing to take this risk, but now they are. The public clamor has subsided to a certain extent and they are simply using their wires.

MR. SEYMOUR:—Are the companies conducting their business without the Board of Electrical Control's permission?

DR. WHEELER:—Do you mean to say permission in respect to the Board declaring that the wires are safe?

MR. SEYMOUR:—No sir. Permission from the Board of Electrical Control to go on and do the lighting, as the public understand that they were shut down by order of the Board of Electrical Control. I want to know whether they have gone to work without the permission of the Board of Electrical Control or not.

DR. WHEELER:—I do not understand that the Board of Electrical Control has ever refused permission to any company to carry on the electrical business. The board simply passed a resolution at one time requiring the companies to cease the use of such wires as were not properly insulated, and until they could procure a certificate from the expert of the board that the wires were insulated and safe. They have not secured such a certificate, and they have made some effort which would prevent wires from passing an examination, and the matter lay in that condition sometime until within the last few days. Now they have decided that they will take the chance of whether the wires are safe or not—a position which is quite natural for them to take; and I should say quite sensible, because I do not think anybody could undertake to guarantee that all their wires are safe. They are simply operating them themselves, and if their wires are proven to be unsafe, as shown by any accident, they will simply be responsible for operating such wires. The board has not declared that any company shall not carry on its business—that is, as I understand it. I do not undertake the legal part of the business; but I do not think that there is any dispute about that.

MR. SEYMOUR:—Then I understand that the companies are going on and ignoring the Board of Electrical Control. If one company has that right they all have that right. If they are taking that position the Board of Electrical Control will practically have to take a back seat. If the companies now are stronger and more important and are simply defying the Board of Electrical Control, why we must know it.

DR. WHEELER:—I do not think the companies have any intention of defying the Board of Electrical Control, and I do not think that the board has any idea of taking a back seat. The board passed that resolution evidently with the intention of really placing the responsibility where it should be. As there was a question at the time of who was accountable, and to make that perfectly clear, the board passed a resolution that no unsafe wire should be operated. If the companies choose to go on operating wires, and they are unsafe, then the companies are responsible, and if any harm results, they must answer for it.

MR. SEYMOUR:—They had that responsibility before.

DR. WHEELER:—Oh, yes. But there was a good deal of misunderstanding. There were a great many of the newspapers which seemed to think that the board was responsible. And the board tried to make its position perfectly clear by simply passing that resolution.

MR. SEYMOUR:—I think the fact has come out that the authority to destroy the property of electric companies does not exist in the Board of Electrical Control, or any other board; and they have probably taken a different view of that question. There are other ways of stopping business than by destroying property; and the fact that the city would be responsible for the destruction of property probably modified their views in the Board of Electrical Control. I like to get at the facts in these matters, and to defend our business.

MR. CURTIS:—It seems to me that one of the most important questions that has come up to-night has been the question of the comparative cost of tunnels, and what are called subways. Mr. Maver has instituted a comparison between the cost of tunnels for New York and the cost of subways, and the general conclusion from what I have heard to-night seems to me to be that tunnels would cost about $450,000 per mile, and subways would cost something like $3,000 per duct per mile. I cannot see why there should be such a great difference between the cost of subways and the cost of tunnels. Of course, there is a great difference—a tunnel requires a larger excavation, and it requires building the walls of very much heavier material, and it requires special removal and replacing of all the gas mains or electric wires which are there at present, also water mains and steam conduits. But as far as the cost of the tunnel itself is concerned, I do not see why that should be very much greater than the cost of the more expensive or more improved forms of subways. The advantage of tunnels in several respects is certainly very great. Service connections to the house can be made simply by boring through the walls of the tunnel right into the front cellar of the house. The water pipes and the gas pipes and anything that comes along in the nature of a new system—probably something will come along in a few years—can be introduced in the same way. When you consider the saving of cost that can be realized in the next five or

ten years in the replacing of the old gas pipes and the old water pipes and the fixing of the sewers, and the constant shifting and adding to and testing of the electric light wires and electric wires of all kinds that would be necessary in order to keep such a system in working order, it seems to me, if it did cost something like $450,000 a mile, at the outset, it is not to be thrown out of consideration at all. If thirty years ago somebody had said, in answer to the proposition to connect New York and Brooklyn by a bridge, that such a bridge would cost fifteen millions of dollars, that would have settled it. But capital was forthcoming. And I do not see why, in the greatest city of this country, capital should not be forthcoming to put the subways or tunnels, or whatever they are, in condition to give the most desirable service possible. It seems to me it is largely a financial question. I do not myself see how any satisfaction can be got by the public or by private interests out of the present way of operating the wires by private corporations. It seems to me a very remarkable state of affairs that a private corporation should be allowed to have a monopoly of building subways for all kinds of electric wires, and that a Board of Electrical Control, or anybody for that matter, should have the authority to compel people to put them into those ducts. Because it amounts to an authority, they will not allow them to use them unless they put them underground. There are no other underground conduits so they have got to go there, and it is a very remarkable state of affairs that the company has got to put its wires underground in conduits, but cannot guarantee their working or take care of them properly. It appears to me that much the best plan is for the city to put the streets in such a condition that all kinds of service —gas, electricity, whatever it is —can be had to the best advantage, even though it may cost a great many millions; I think Mr. Maver said that in the principal streets to replace the present subways by tunnels would cost in the neighborhood of thirty millions. Well, if it cost thirty millions to give New York a system of water, gas, electric light, steam heat and sewerage, where there will be perfect access to the houses and where it will accommodate all these forms of supply, it would be a very desirable thing, and it would well repay such an investment. It, perhaps, costs several hundred thousand dollars a mile to pave a wide street in the best style, but a fine pavement is very important, and it is also most important that a city should be supplied with its light in the most convenient way. I think we ought to look far ahead in this matter and not consider whether the cost is three thousand dollars or one hundred thousand dollars per mile. Of course, it is impossible to judge what the consequences have been; and they do not furnish us with the means of arriving at any conclusion But, although it is a very old idea, nobody has advocated with any emphasis at all the best investment of sufficient capital to obtain the best means of supply for all these conveniences.

Adjourned.

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